3.2.2 Motion with non-uniform acceleration

	Learning outcomes			Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:			
(a)	drag as the frictional force experienced by an object travelling through a fluid			
(b)	factors affecting drag for an object travelling through air			HSW6
(c)	motion of objects falling in a uniform gravitational field in the presence of drag			HSW9
(d)	**(i)**	terminal velocity		HSW1, 5
	(ii)	techniques and procedures used to determine terminal velocity in fluids.		**PAG1** e.g. ball-bearing in a viscous liquid or cones in air. HSW4 Investigating factors affecting terminal velocity.

(6) M - Design elements of a practical including a suitable range form preliminary
(7) S - Describe a method to determine terminal velocity.
(8) C - Suggest adaptations to an investigation to improve uncertainty

Lesson 4 Drag investigation

Activity: Determine the terminal velocity of a falling object in fluid.

Read and sheet and bind in. Plan and complete the investigation in your lab book

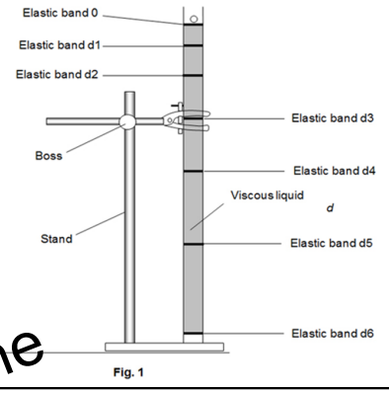

Fig. 1

Extension: Consider adapting the investigation to ensure that measurements are taken only after TV is reached.

Use slow motion phone camera.

Every 0.1 second.

8mm ball bearing

(6) M - Design elements of a practical including a suitable range form preliminary
(7) S - Describe a method to determine terminal velocity.
(8) C - Suggest adaptations to an investigation to improve uncertainty

Lesson 3.5 Drag investigation

Activity: Complete the follow up questions

Extension: Why is a similar object of greater mass, falling with greater TV?

Answers for method sheet

1 No the students did not take measurements of the terminal velocity. (*1 mark*)

They found an average speed for the cone as it fell. (*1 mark*)

2 **Either** students could have added markers every 0.5 m and, using the stopwatch, found the time for each 0.5 m. (*1 mark*)

This would enable them to establish whether terminal velocity had been reached and a more accurate value for terminal velocity. (*1 mark*)

Or students may suggest filming the event and using the markers and the frame times to collect more accurate data. (*2 marks*)

3 Students should have collected data for at least six different masses. At least four of the data should show an increase in average speed. Only two should show that the speed reached a maximum value. Students should be able to identify what makes a suitable range. Mark this based on their results and comments. (*2 marks*)

4 It would be easy to state timing here as that usually is the correct answer. However, if they have increased mass by 0.2 g using a 1 d.p. balance then their percentage uncertainty in the mass is the largest error. (*1 mark*)

The precision error of a 1 d.p. balance is 0.1 g. A 2 d.p. balance has a precision error of 0.01 g so this would have reduced the percentage uncertainty in measuring the mass. (*1 mark*)

5 The cone accelerates until the drag equals the weight. (*1 mark*)

As the weight increases the cone accelerates for longer. (*1 mark*)

At some point the cone is so heavy that it cannot reach its terminal velocity in the time allowed. (*1 mark*)

The time will not increase. (*1 mark*)

Example data

Actual data is given below.

Height of drop	4.5 m
Diameter of cone	16.5 cm
Radius of paper circle	10 cm
Mass of cone	2.4 g

Mass / g	Time / s
0.0	3.31
0.5	3.28
1.0	2.87
1.5	2.85
2.0	2.41
2.5	2.47
3.0	2.36